Low-Noise Receivers: Solid-State Pump Source for S-Band Traveling-Wave Masers

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Low-noise traveling-wave masers have been used by the Jet Propulsion Laboratory Deep Space Network for ten years. The requirements for the maser pump source are presently met by reflex klystron oscillators, although other microwave energy sources have been tested and evaluated on the basis of cost, reliability, output power, tunability, frequency stability, and power stability. Gunn-effect diode oscillators have recently reached a stage of development that makes them superior to the reflex klystron oscillator. This article describes a Gunn-effect oscillator that has been tested, packaged, and evaluated in the laboratory and is now ready for installation in the Deep Space Network.

I. Introduction

The traveling-wave masers presently used in the Deep Space Network use reflex klystrons as pump sources. The limited electronic tunability and lifetime, as well as the high-voltage requirements of the reflex klystron have made desirable the development of a solid-state pump source that would serve as a suitable replacement. This article describes a new maser pump package using a Gunn-effect oscillator.

II. The Gunn-Effect Oscillator

Recent improvements in Gunn-effect diode performance have made possible a solid-state device with sufficient power and stability to meet the pump requirements of a traveling-wave maser (TWM). TWM pump frequency, stability, and power requirements have been previously reported (Ref. 1). The varactor-tuned, Gunn-effect oscillator used is a Varian model VSU-9012Y, which is electronically tunable from 12.6 to 12.9 GHz. Varactor (diode) tuning permits very fast tuning rates and is accomplished by varying the voltage applied to the tuning bias terminal of the oscillator. By amplitude modulating the tuning bias voltage at a 100-kHz rate, the Gunn oscillator can be frequency modulated across its entire tuning range. Frequency modulation of the TWM pump source reduces the frequency stability requirements and permits the TWM to be tuned across its full range with no further pump frequency adjustment.

III. Control Circuitry

The control unit for the Gunn oscillator is mounted in the maser control rack and operating voltages are connected to the pump package by antenna cables (Fig. 1).

Unlike the reflex klystron, the Gunn-effect oscillator operates from a low-voltage power source. The control unit uses three, relatively low-cost, commercial voltage-regulated power supplies. The Gunn oscillator bias voltage (7.0 V at 1A) has no front panel adjustment, as the proper operating voltage adjustment is made at the time of installation and is regulated at that point. The tuning varactor bias voltage is adjustable through one of two 10-turn counting dials (duodial) on the control panel. Figure 2 shows a correspondence of the package output frequency and power to the varactor tuning duodial and voltage. The second duodial adjusts the frequency modulation control voltage.

IV. Pump Package Description

The Gunn-effect oscillator is mounted on a temperature-controlled heat sink in the pump package together with a combined protective and audio oscillator circuit (Fig. 3). The protective circuit prevents the application of a negative or excessive voltage to the Gunn bias or tuning varactor terminals and the 100-kHz audio oscillator modulates the voltage at the tuning varactor terminal of the Gunn oscillator. Amplitude modulation of the tuning varactor bias voltage results in frequency modulation of the Gunn-effect oscillator.

A commercial temperature controller is mounted on the inside wall of the pump package and is set to maintain the heat sink temperature at 45°C ± 0.5°C over an ambient temperature range of 15°C to 35°C. A 28-V power supply for the temperature controller is mounted in the rear of the maser control rack and does not require adjustment. The Gunn-effect oscillator assembly is readily interchangeable with the reflex klystron and has been installed in an existing pump package. The only modification required was the drilling of four holes necessary to mount the temperature controller. No new or special antenna cabling is needed and only minor changes in the maser control rack and junction box wiring are necessary.

V. Performance

The Gunn-effect oscillator has been used in the lab to pump a new S-band TWM, which has a superconducting magnet. This combination of magnetic field and pump source versatility has shown performance superior in several ways to that of other S-band TWMs. The maser gain, during single-frequency operation, is comparable to that obtained when using a reflex klystron, but frequency modulation of the oscillator produces broadband energy sufficient to increase the maser gain 2 dB above that obtained when pumped by a frequency-modulated klystron. Stagger tuning of the maser/magnet combination separates the maser into two halves and permits an increase in maser bandwidth (Ref. 2). Figure 4 demonstrates that through wide separation of the maser halves, simultaneous maser operation at two frequencies separated by 100 MHz is possible. This kind of two-frequency operation requires wideband pump energy previously unavailable from a single pump source.

References

1. Clauss, R. C., and Quinn, R. B., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol. IX, pp. 128–136, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1972.

2. Clauss, R., Wiebe, E., and Quinn, R., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol. XI, pp. 71–80, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1972.

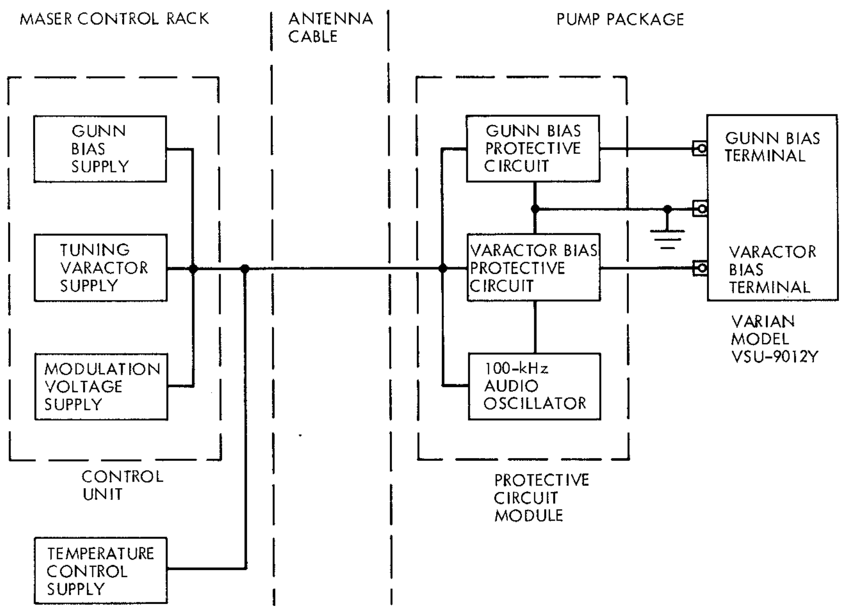

Fig. 1. Block diagram of Gunn-effect oscillator and related control circuitry

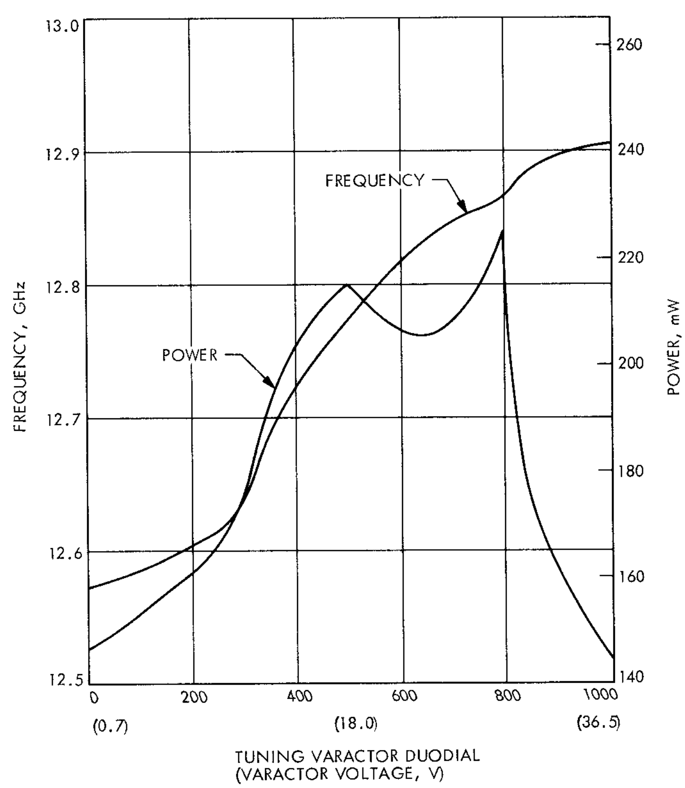

Fig. 2. Varactor bias voltage vs frequency and power

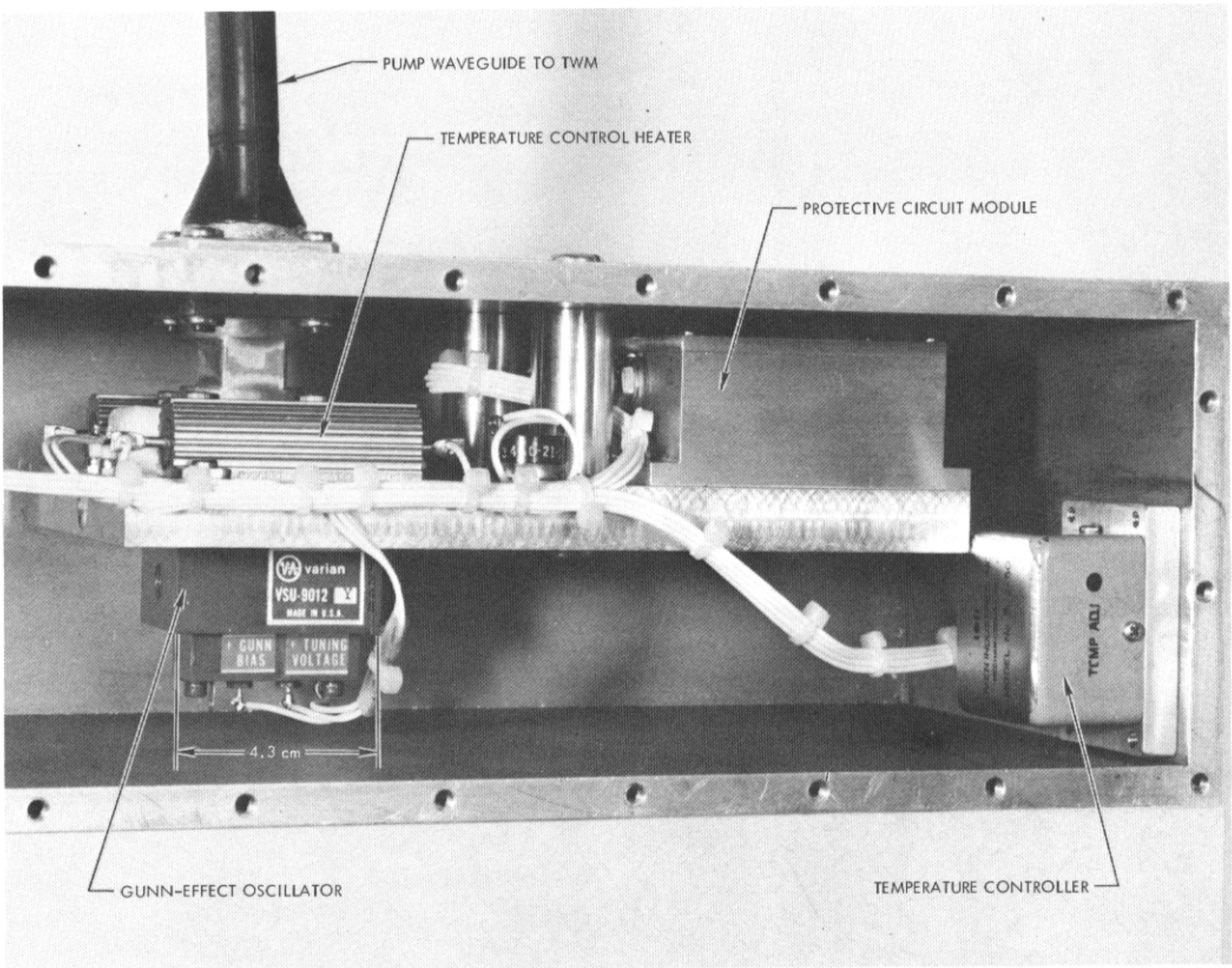

Fig. 3. TWM pump package with Gunn-effect oscillator

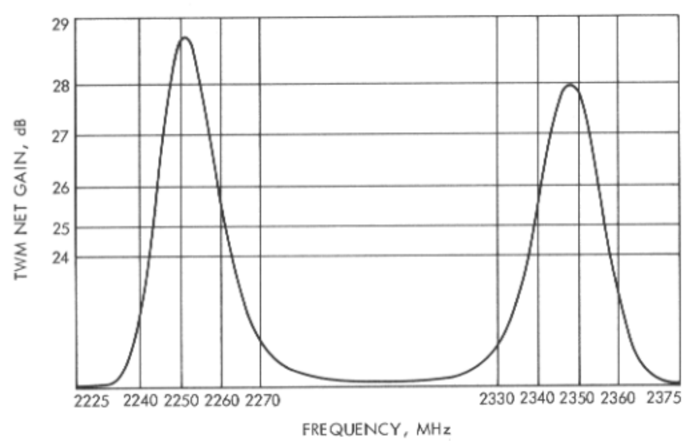

Fig. 4. Simultaneous two-frequency operation